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The concept of mineralogical maturity and the origin and evolution of dune fields in the western United States

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Introduction

Studies of dune fields in the western United States show that mineralogical maturity can provide new insights into the origin, evolution and long-term history of eolian sand bodies. Mineralogical maturity can be defined as a compositional state of a clastic sedimentary body wherein there is a dominance of quartz and an absence or minority of less-resistant particles such as feldspars, detrital carbonates or lithic fragments. Sandstones that meet this definition are classified as quartz arenites or orthoquartzites. Many of the world's great sand seas in Africa, Asia and Australia are quartz-dominated and thus can be considered to be mineralogically mature.

In the western United States, the largest dune fields are found in the semiarid central and southern Great Plains. Smaller dune fields are found in the northern Great Plains, the Basin and Range province (including the Mojave and Sonoran Deserts), the Colorado Plateau, and intermontane basins of the Rocky Mountains. Studies conducted over the past 10 years show that these dune fields have a wide range in degree of mineralogical maturity. Major oxide analyses provide an indirect but quantitative estimate of mineralogy, where key oxides serve as proxies for common minerals found in dune sand. Examples include SiO_2 (quartz), K_2O (K-feldspar), Na_2O (plagioclase), Al_2O_3 (all feldspars) and CaO and MgO (carbonates).

Based on geochemical criteria (see Figure 1), dune fields of the western U.S. fall into three categories of mineralogical maturity: immature, intermediate, and mature. Examples of immature dune fields include many of those found within the Mojave Desert, such as the Cadiz and Danby dunes of California. Intermediate-maturity dune fields include several found in the central Great Plains (Fort Morgan and Wray dune fields of northeastern Colorado) and some in Rocky Mountain basins (Killpecker dunes, Wyoming). Mineralogically mature dune fields include larger sand bodies in the central and southern Great Plains (Nebraska Sand Hills and the Muleshoe and Monahans dunes of Texas and New Mexico), as well as smaller dune fields in the Sonoran Desert (Algodones, California and Parker, Arizona).

Mojave Desert dune fields may be mineralogically immature because they are not derived from major river systems but rather from small streams draining granitic mountain blocks. Furthermore, the dune fields are confined largely to structural basins adjacent to the source mountains themselves. Thus, sediments in these dunes have undergone little transport by either fluvial or eolian processes. In contrast, intermediate-maturity dune fields are those fed by major fluvial systems, such as the South Platte River. Sediments in these dunes underwent a considerable amount of fluvial transport prior to eolian transport, which concentrated quartz in the downstream reaches of the source rivers, where the dune fields are located. Intermediate-maturity dune fields are found in relatively flat, open landscapes, where there are fewer limitations on eolian transport compared to intermontane desert basins.

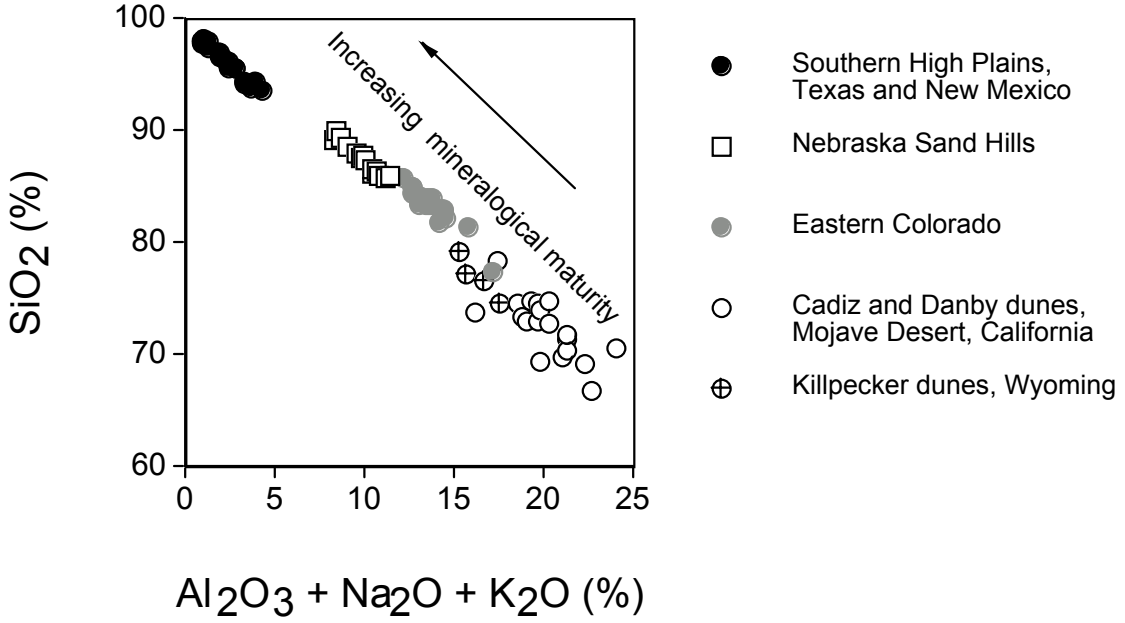

Figure 1. Plot of bulk SiO_2 (reflective of quartz content) vs. $Al_2O_3 + Na_2O + K_2O$ (reflective of feldspar content) in dune fields of the western United States. Data for the Cadiz and Danby dunes from Zimbelman and Williams (2002); data for the Killpecker dunes from Gibbons et al. (1990); data for all other dune fields from this study.

Some dune fields, such as the Algodones dunes of California and the Parker dunes of Arizona, may have achieved a degree of mineralogical maturity largely by inheritance. Both of these dune fields are derived from sediments of the lower Colorado River. Lower Colorado River sediments are themselves quartz-dominated, probably because they contain a large component of sand derived from mineralogically mature sandstones of the Colorado Plateau. The Algodones dunes show only slight enrichment of quartz (as measured by SiO_2 content) compared to medium and fine-sand-sized Colorado River sediments.

In contrast, quartz-dominated dune fields of the central and southern Great Plains did not achieve mineralogical maturity solely by inheritance. It is true that the Nebraska Sand Hills and the Muleshoe and Monahans dune fields of Texas and New Mexico may have been fed, at least in part, by large river systems (the North Platte and Pecos Rivers) that concentrated quartz by fluvial processes. In addition, dunes in both areas probably inherited sand from older, quartz-rich eolian sheet sands (Pliocene sands in Nebraska and the Pleistocene Blackwater Draw Formation in Texas and New Mexico). Nevertheless, dunes in both regions are richer in quartz (higher in SiO_2 and depleted in K_2O, Na_2O and Al_2O_3) than any known source sediment or combination of source sediments. It follows from this that less-resistant particles, such as feldspars, have been depleted within the dune fields themselves, most likely by ballistic impacts from strong winds. Thus, mineralogically mature dune fields of the Great Plains reflect (1) relatively old ages for genesis of the dune fields, (2) extended periods of eolian activity as opposed to extended periods of stability, or (3) a combination of both of these factors.

References

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